Accelerated Coated Conductor Initiative: Progress Report

Los Alamos National Lab: Vladimir Matias

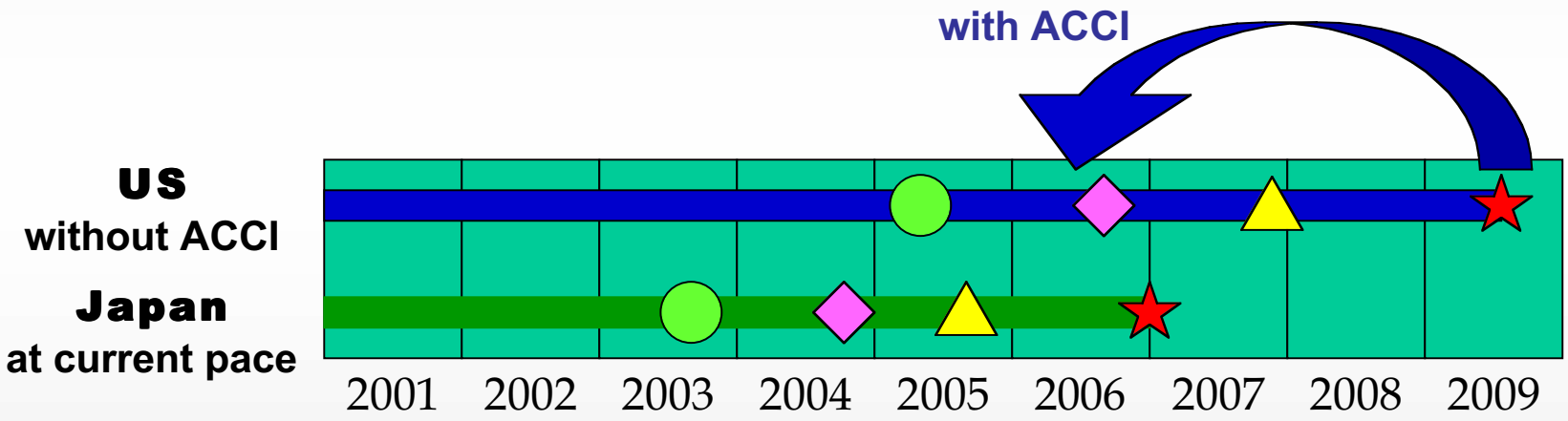
Oak Ridge National Lab: Fred List

Goal: Ensure US leadership in applications of HTS wire to electric power by providing new resources for accelerated research and development efforts.

- Industrial Overview Committee, Sept. 2000

US vis-à-vis International Efforts

- Japan and Europe are making great strides in Coated Conductor development with help of greater government funding.
- US was losing the lead prior to ACCI.



100m tapes available from prototype production

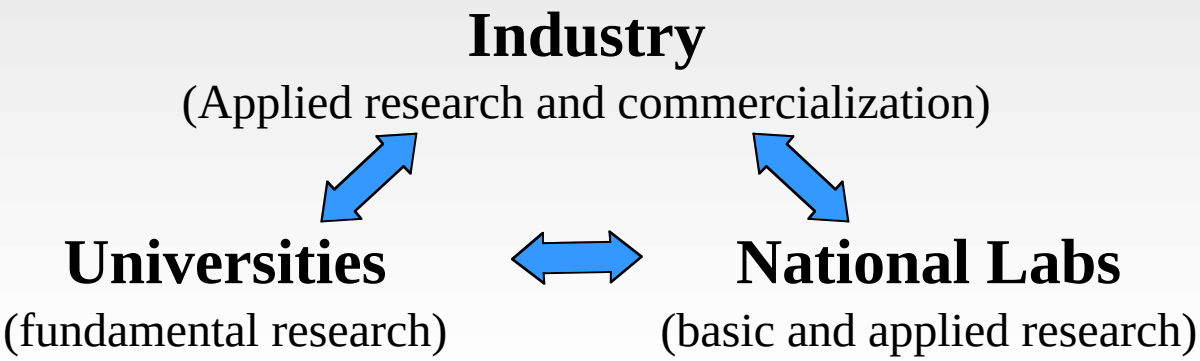
Commercial tapes available in km lengths

Prototype transformers, generators, motors, cables

Initiate market penetration

Source: LANL, ORNL, ISTEC

Roles of Various Parties in Coated Conductor Development



National Labs have a prominent role in developing:

- A knowledge base for Coated Conductors (CC); in collaboration with universities
- A technology base for CC Processes; with collaboration with industry
- Applications demonstrations; in partnership with industry

LANL Effort

Los Alamos National Lab Team for Accelerated Coated Conductor Initiative

- Coatings:

  New Staff: Vladimir Matias, Brady Gibbons, Larry Bronisz

  Paul Arendt, Steve Foltyn, Eric Peterson, Randy Groves, Paul Dowden, Yates Coulter, Ray DePaula, Liliana Stan, Quanxi Jia

- Applications:

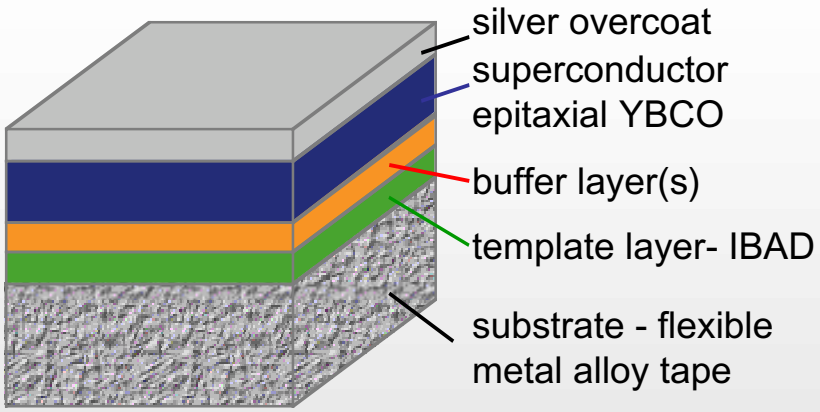
  Jeff Willis, Alp Findikoglu, Steve Ashworth

Funding FY2001: $2600K

$700K operating costs and $1900K capital costs

Building on the Success of LANL Coated Conductors

HTS Tape Materials System



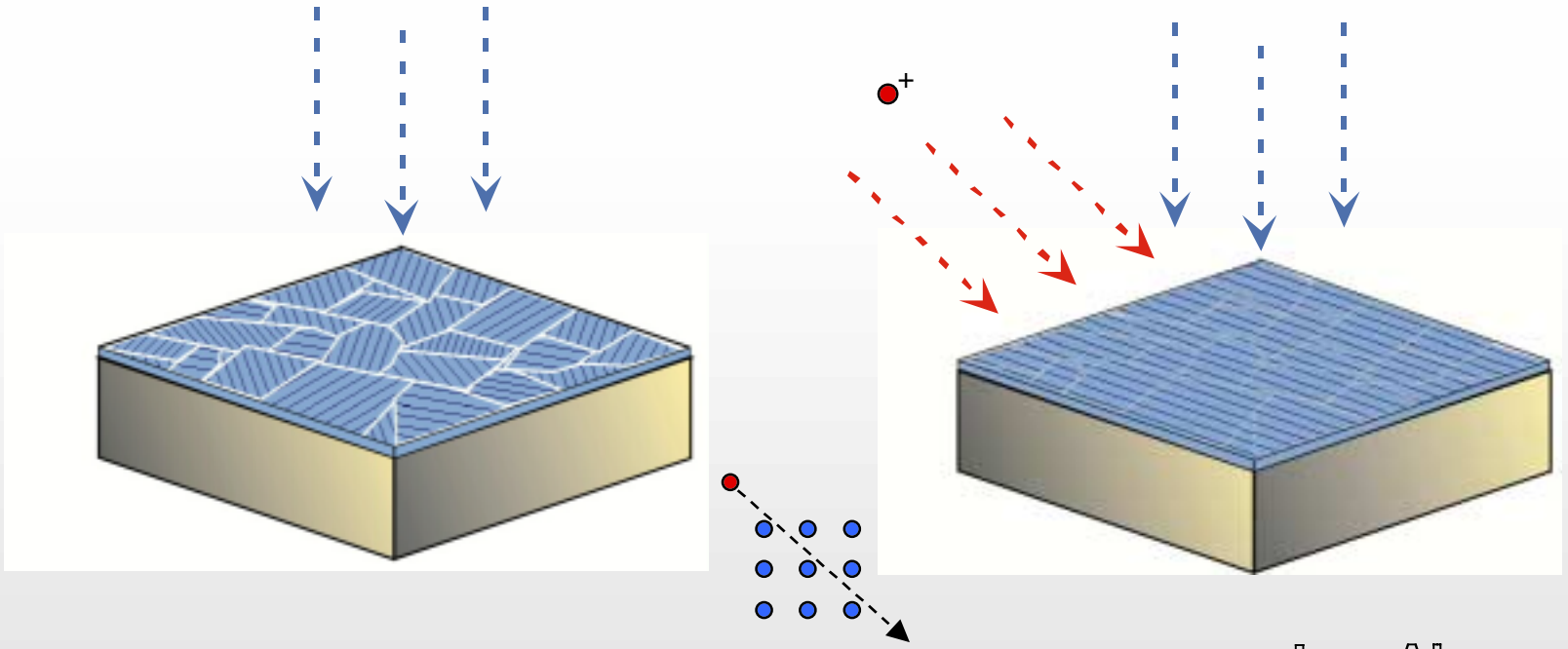
- Meter lengths of YBCO coated conductor have been fabricated by IBAD and PLD
- Over 120 A have been achieved in 1 cm wide meter long tapes
- Ion Beam Assisted Deposition of yttria-stabilized zirconia or magnesia is used as a template layer

Ion Beam Assisted Deposition for Film Texturing

Non-single crystal substrate

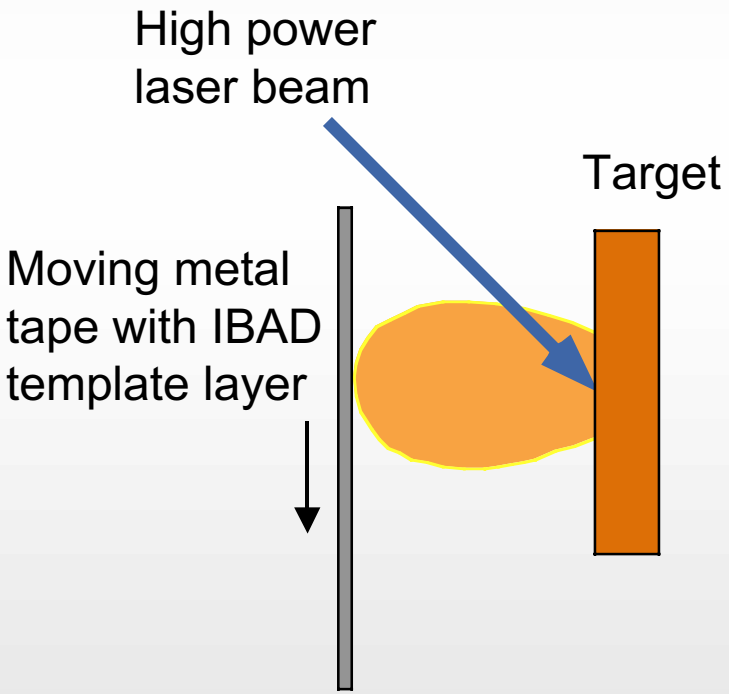
Film deposition produces a polycrystalline film or a film with fiber texture

With IBAD one can align the grains in the plane of the film



Pulsed Laser Deposition is a Versatile Approach for Oxide Film Deposition

- Pulsed Laser Deposition is used for growth of buffer layers and YBCO on heated tape



Accelerated Coated Conductor Initiative at LANL

- ACCI provides additional funding to accelerate the Coated Conductor research and development efforts
- STC is setting up a new facility dedicated to closer interaction with partners
- New facility will provide unique equipment and expertise for coated conductors
- Ability to evaluate alternate coated conductor approaches
- New facility will also provide a center for applications efforts and complete component design and fabrication

New building at the Los Alamos Research Park

- **Building finished in April 2001**
- **STC Tenant Improvements finished in July 2001**
- **Lab facilities to be finished in September 2001**

Future plans envision six buildings in the Industrial Research Park

STC Facilities at the Research Park

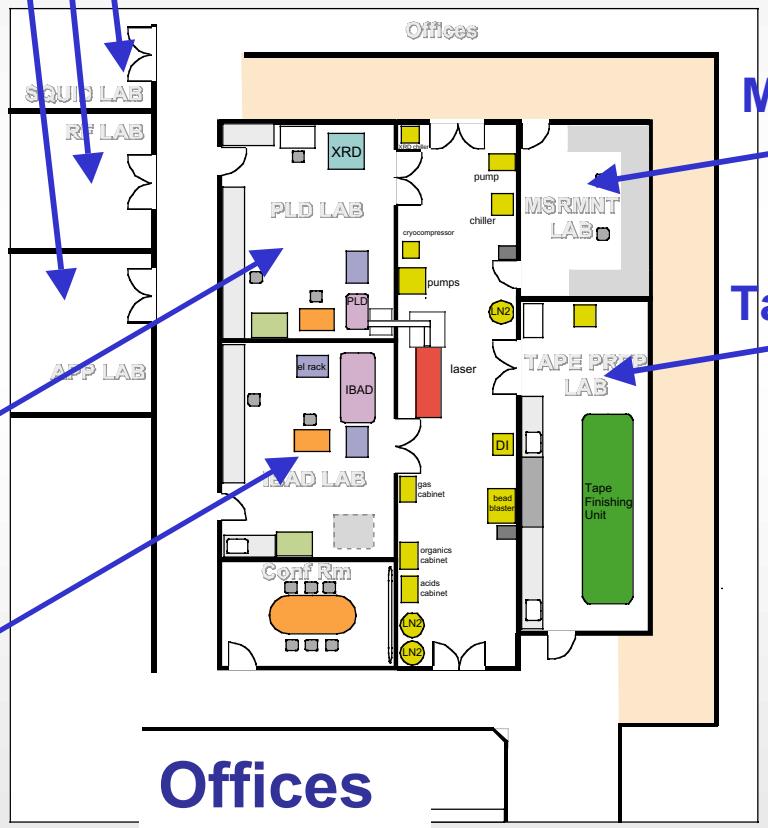
- 10,000 sq. ft. of space
- 7 new labs for Coated Conductor preparation and applications development
- 14 new offices for staff and partners
- Conference room and reception area

Coated Conductor Labs at the Research Park

Key Themes:

- State-of-the-art labs
- Process integration
- Reel-to-reel processing
- In-situ diagnostics
- Applications research
- User facility

Applications Labs



Measurements Lab

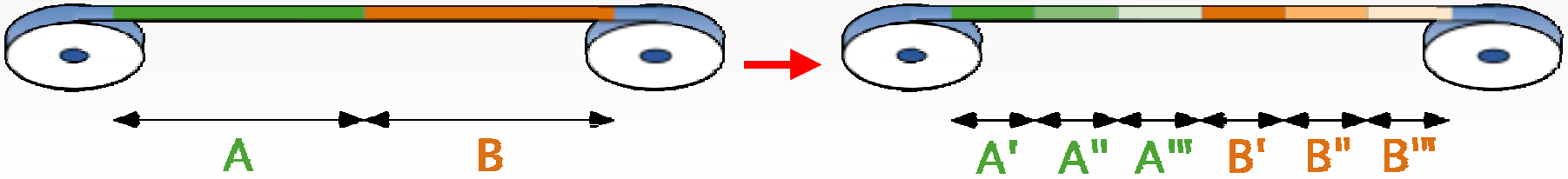
Tape Preparation Lab

Pulsed Laser Deposition Lab

Ion Beam Assist Deposition Lab

Sequential Combinatorial Research from Continuous Tape Processing

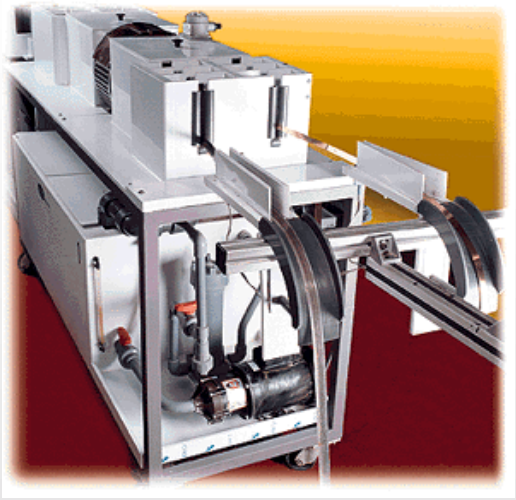
- Continuous tape processing is ideal for exploring process parameters in a sequential way

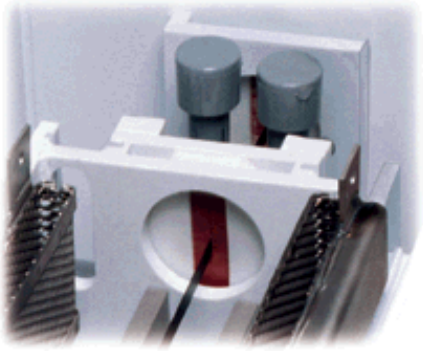


- Our goal is to track positions on tape from one process step to the next and develop a matrix of experiments in a computer database
- Characterization needs to be done in the same way to track experiments
- Such combinatorial research provides for a high-throughput of experiments (100's of experiments in 1 reel)

Tape preparation

- Coated conductors require prepared metal tapes with smooth surfaces
- New industrial-type equipment will process reels of metal tape by wet electrochemistry (etching, electropolishing, electroplating)

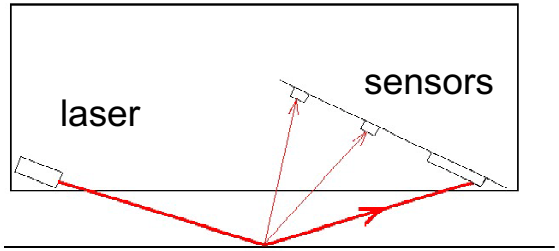




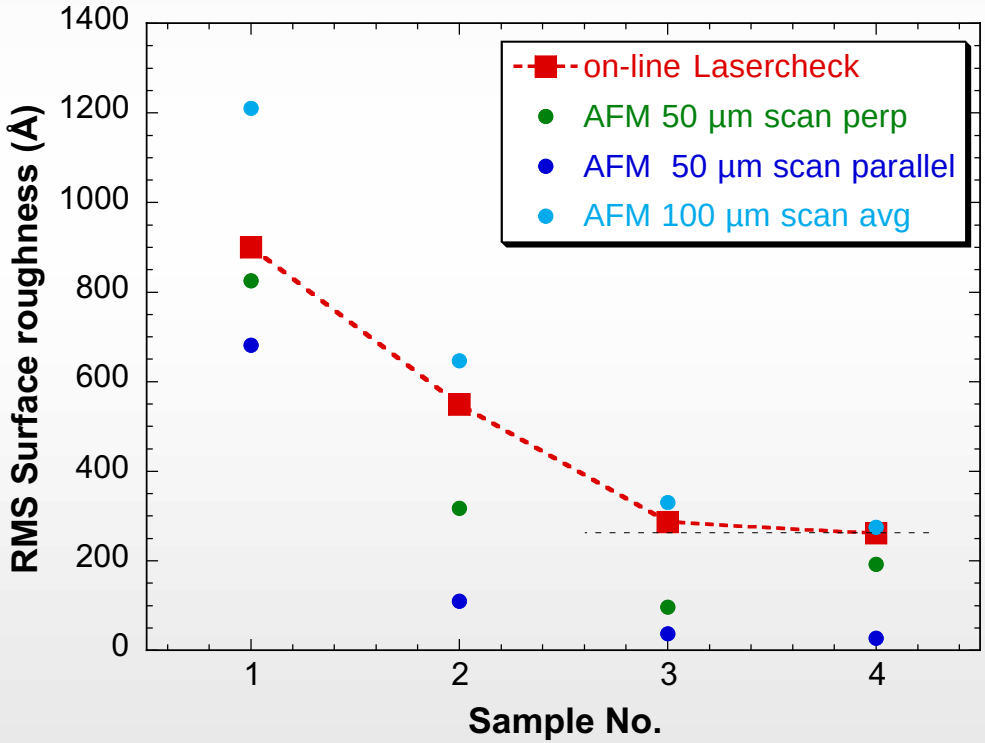
METFAB technologies, Inc.

Laser Scatterometer for Determining Surface Roughness

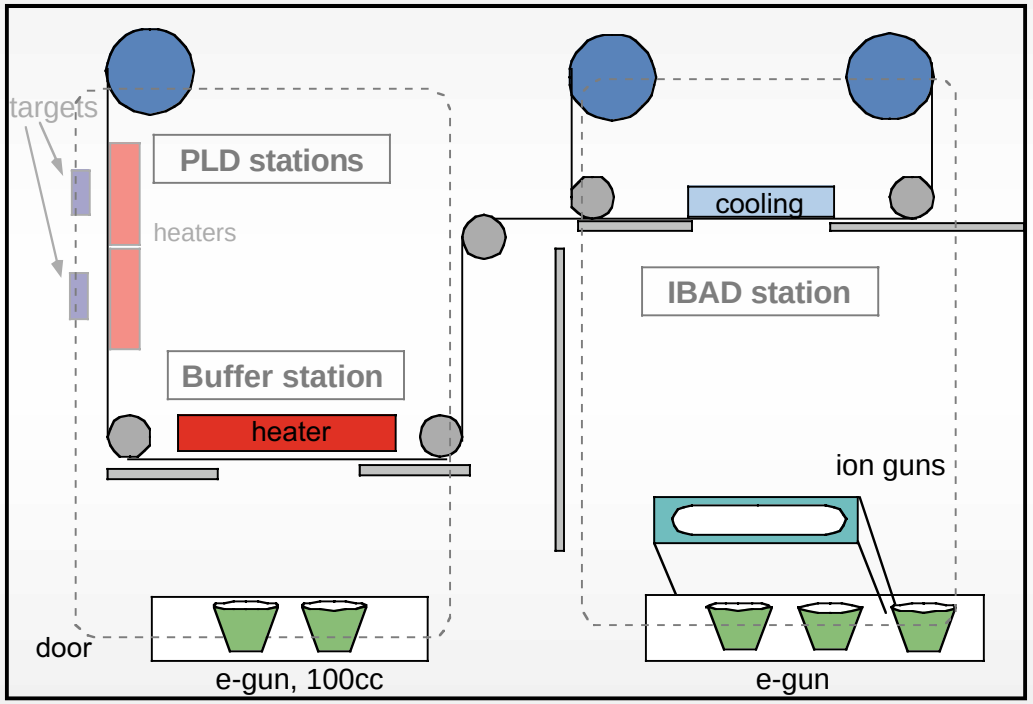
- Laser scatterometer from Optical Dimensions will be used *in-line* for instantaneous roughness measurements



OPTICAL DIMENSIONS LASER CHECK



Proposed IBAD Chamber for Research Park Facility



- Continuous processing of longer lengths of tape (10 - 100 m)
- Capability for process integration
- Initial configuration with IBAD and e-beam evaporation
- *In-situ* monitoring and diagnostics

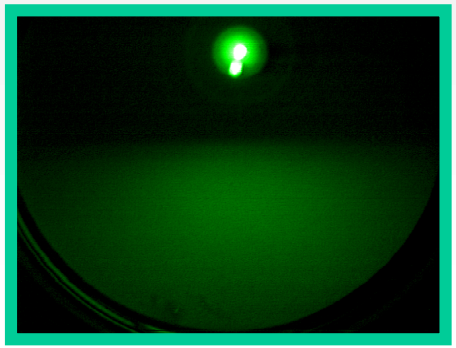
In-situ Monitoring and Diagnostics

A) Reflection High Energy Electron Diffraction (RHEED)

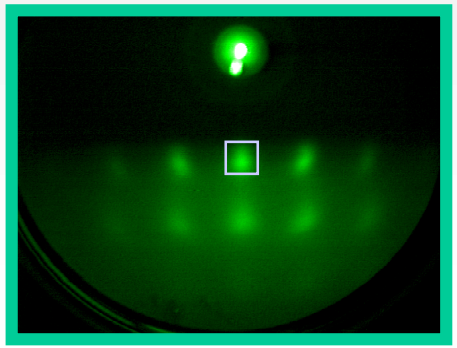
Grazing incidence e-beam diffraction: allows for *real-time* monitoring of the structure of the growing film.

RHEED has proven useful for IBAD film growth

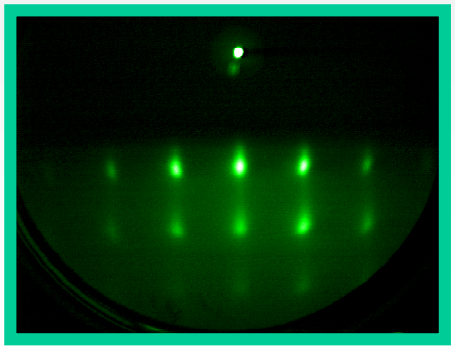
a-Si_3N_4 substrate



after IBAD MgO

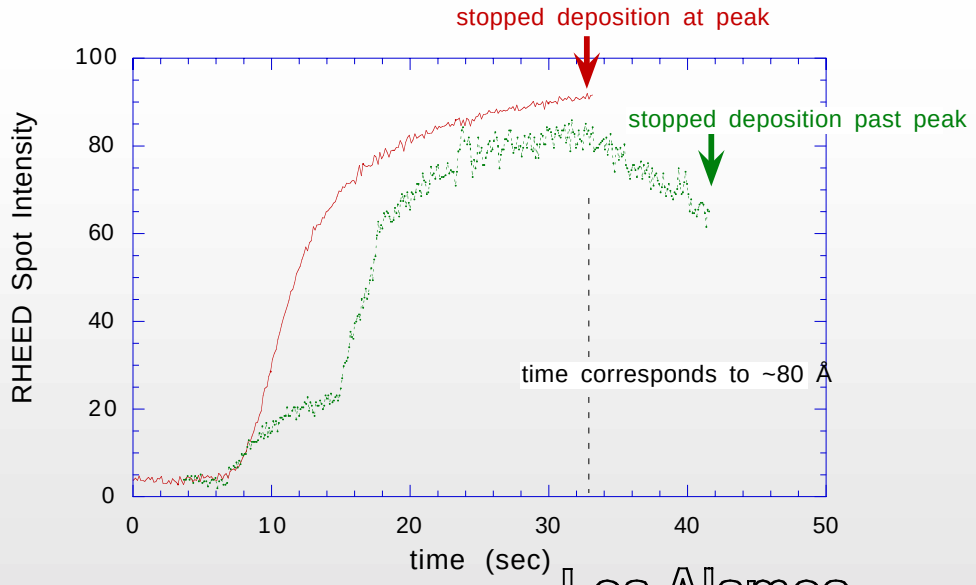


after homoepi MgO

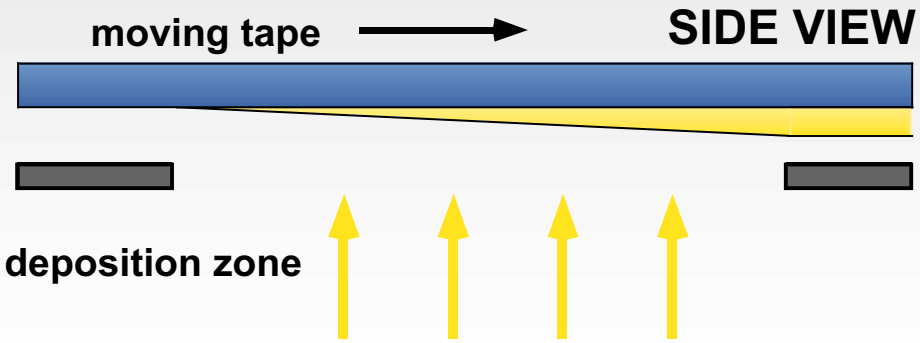


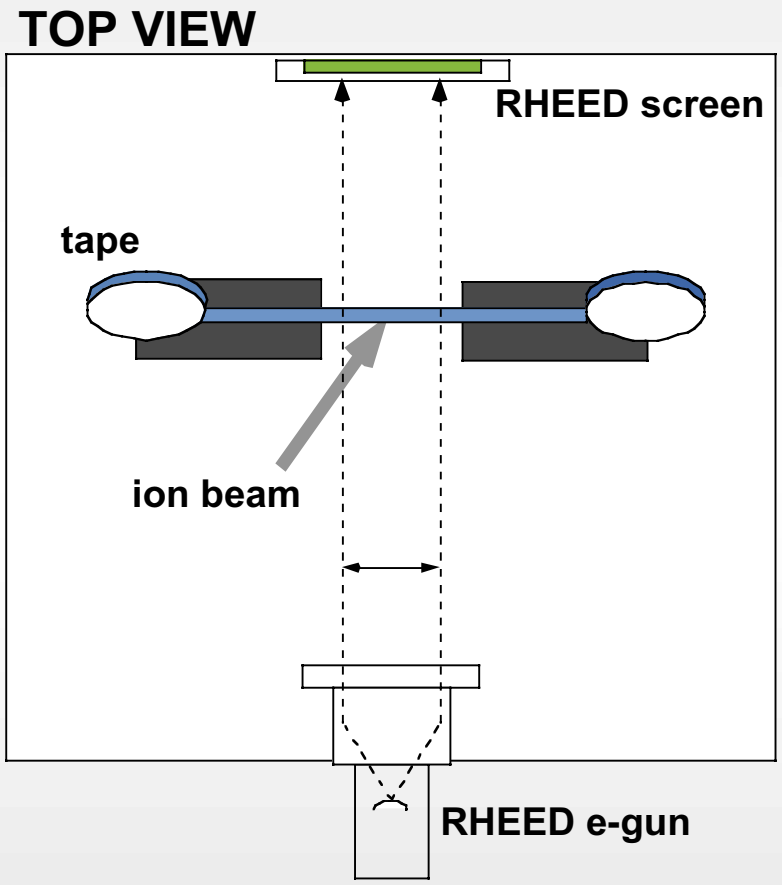
RHEED provides information on:

- Structure of film during growth
- Texture development
- Optimum thickness (MgO)
- Out-of-plane tilt of film
- Grain size



Parallel Scanning RHEED for Continuous IBAD





Problem: sample moves

Solution: track sample with e-beam

- Novel RHEED implementation: scanning RHEED in space and time
- By scanning the RHEED beam along the tape one obtains RHEED images at different stages of IBAD growth

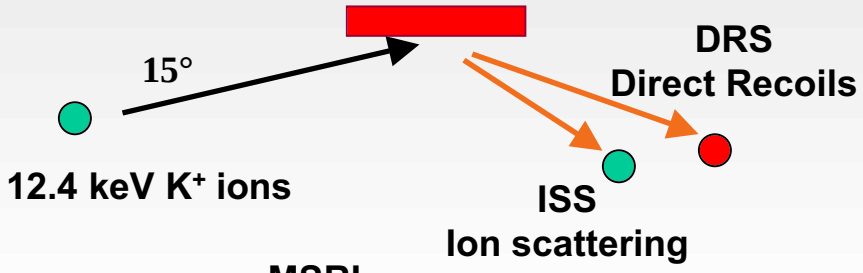
In-situ Monitoring and Diagnostics

A) Reflection High Energy Electron Diffraction (RHEED)

B) Ion scattering for surface analysis

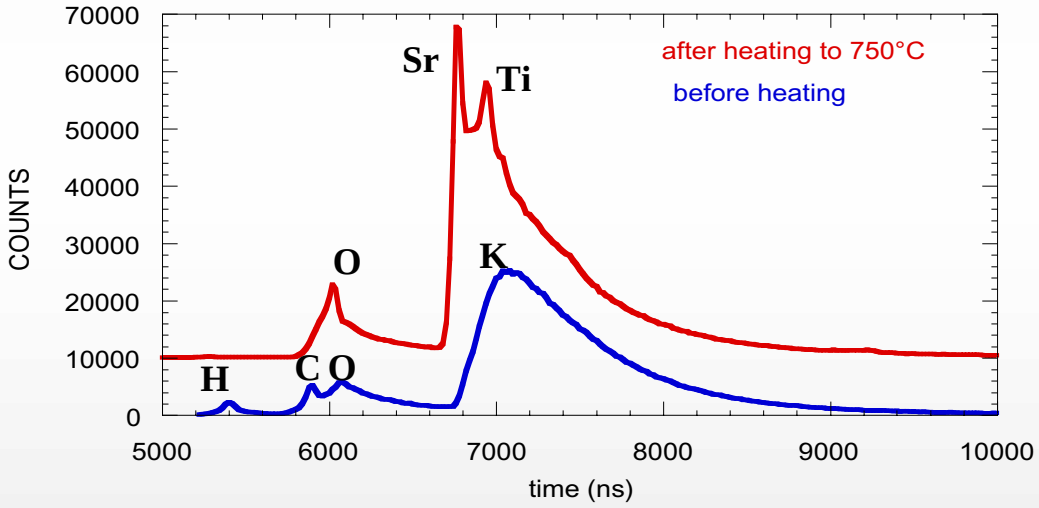
Ion scattering is the most surface sensitive analytical tool. Real power of this tool is obtained in-situ where surfaces don't see any atmosphere.

Time-of-Flight Ion Scattering and Recoil Spectroscopy



MSRI
Mass Spectroscopy of Recoils

$SrTiO_3$ surface (DRS + ISS)



TOF-ISARS is useful for determining:

- top most layers
- residues
- contamination
- complete coverage
- diffusion of elements through layers
- surface layer structure

Mass Spectroscopy Sensitivity ~few ppm

In-situ Monitoring and Diagnostics

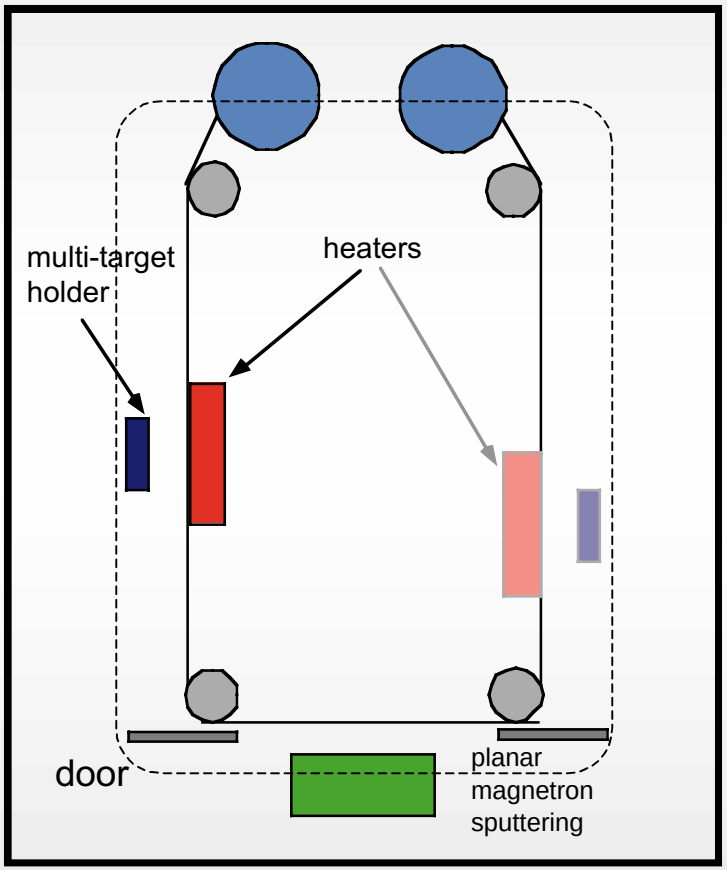
A) Reflection High Energy Electron Diffraction (RHEED)

B) Ion scattering for surface analysis

C) Atomic absorption monitoring for rate control

AA allows for *real-time in-process* monitoring of deposition rates

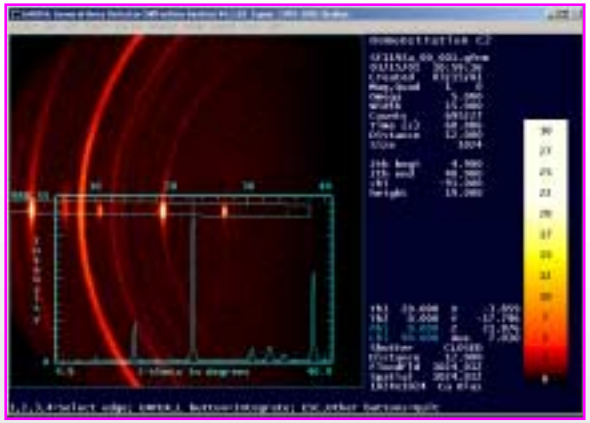
Proposed PLD Chamber for Research Park Facility



Front view

- PLD: 200W Industrial Excimer Laser; allows for fast YBCO deposition (~15 meters/hour of 1 μm thick, 1 cm wide tape)
- Continuous deposition on longer lengths of tape (10 - 100 m)
- Capability for process integration (silver deposition)
- *In-situ* monitoring and diagnostics

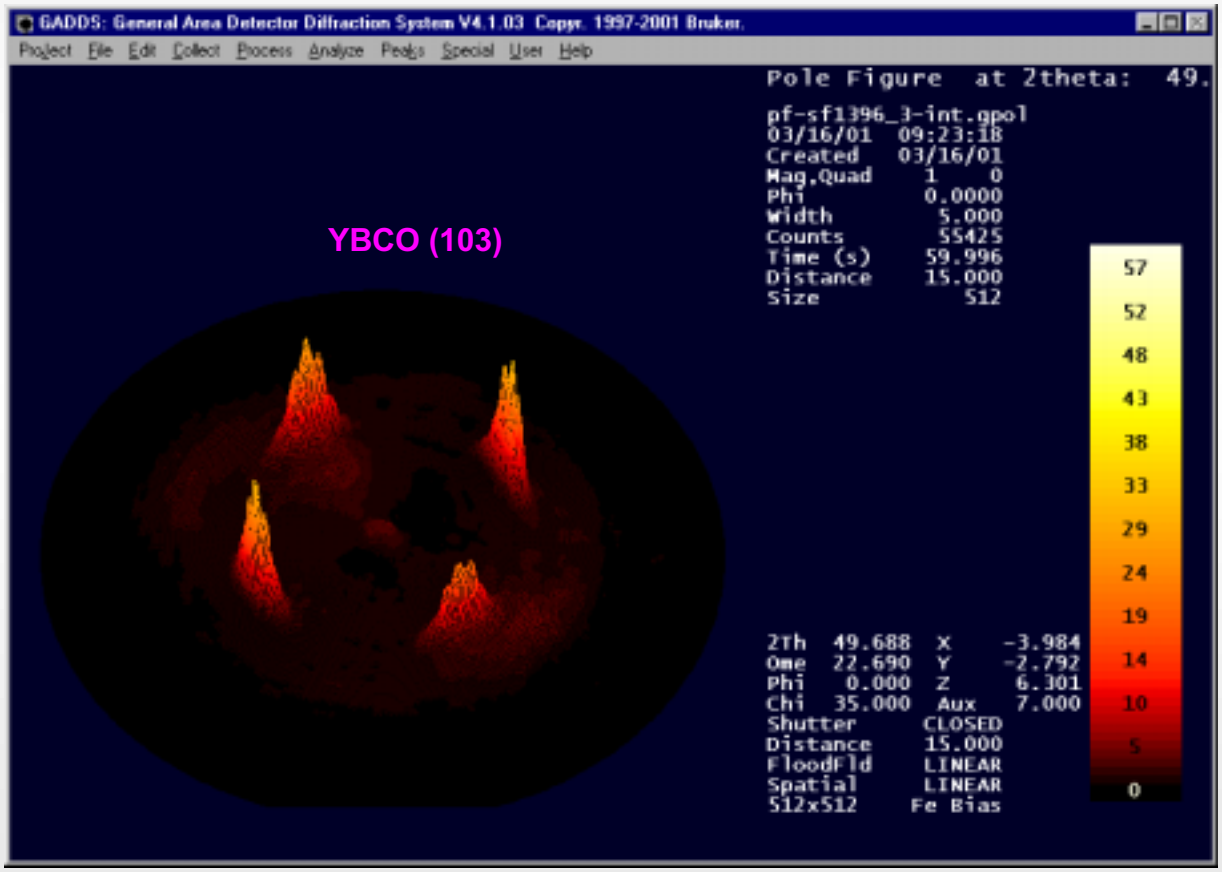
X-ray Diffraction Apparatus

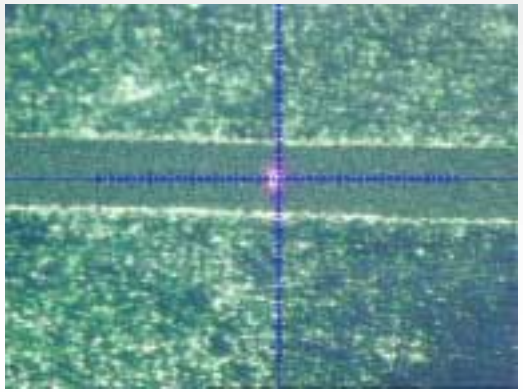


- Bruker D8 Discover XRD
- 2D Position Sensitive Detector (GADDS)
- x,y stage with a minimum 10 μm spot size
- Future capability to include reel-to-reel sample transport

XRD Texture Analysis: YBCO Microbridge

Bruker D8 Discover XRD with GADDS



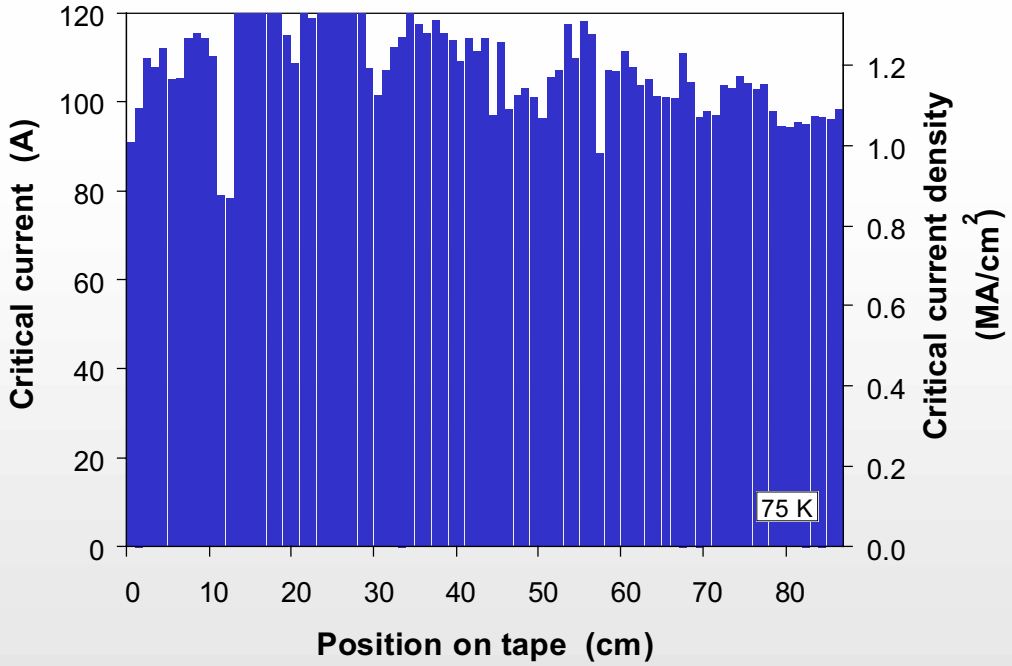


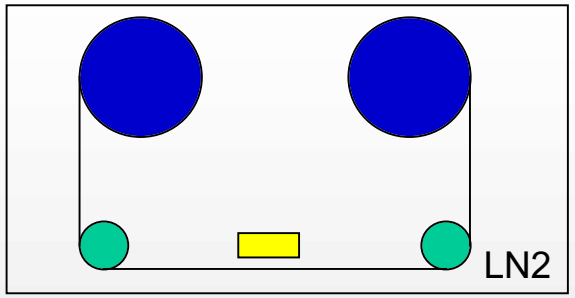
- Microbridge
- 500 micron beam

Pole figures can be performed in ~10 minutes

Measurements Lab

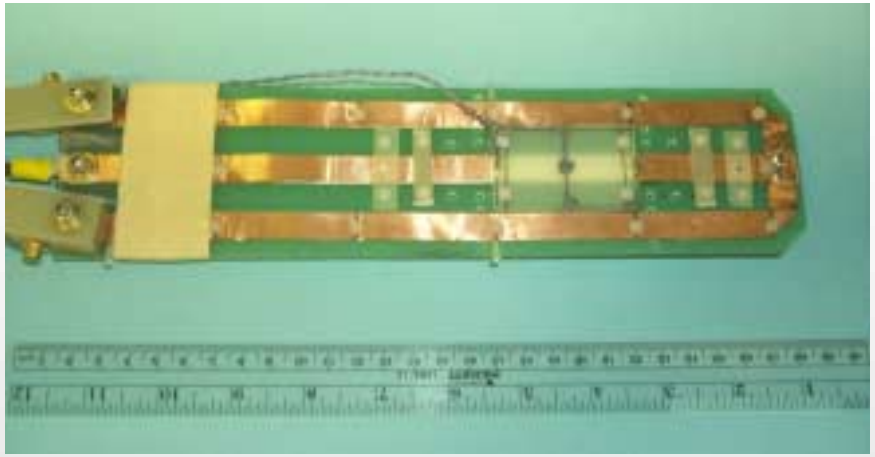
- Reel-to-reel low-temperature transport measurements (contact and non-contact; in magnetic fields up to 4 T)
- Data collection to be integrated with the sample preparation database



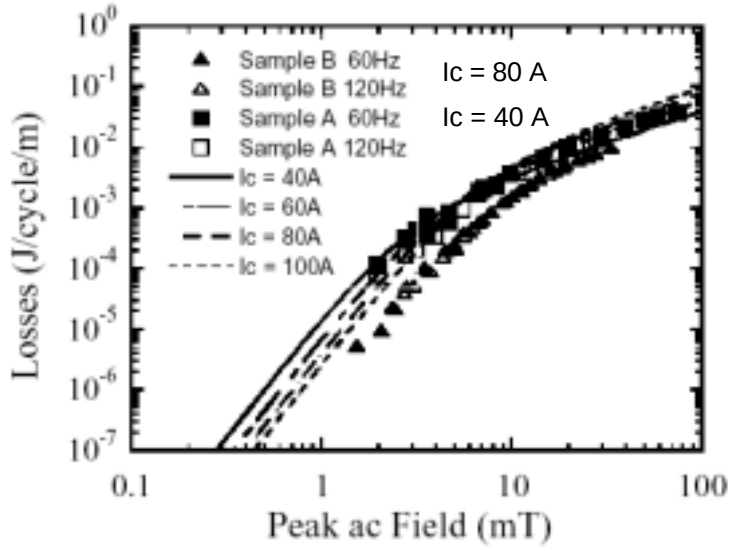


ac Loss Characterization

- Transport and magnetic field ac loss of YBCO tapes by electrical and calorimetric measurement techniques: I <~100 A, T=75-64 K, B=0-100 mT || and ⊥ to tape plane
- Investigate reduction of ac loss in ⊥ field by patterning tapes into strips



Electrical loss probe

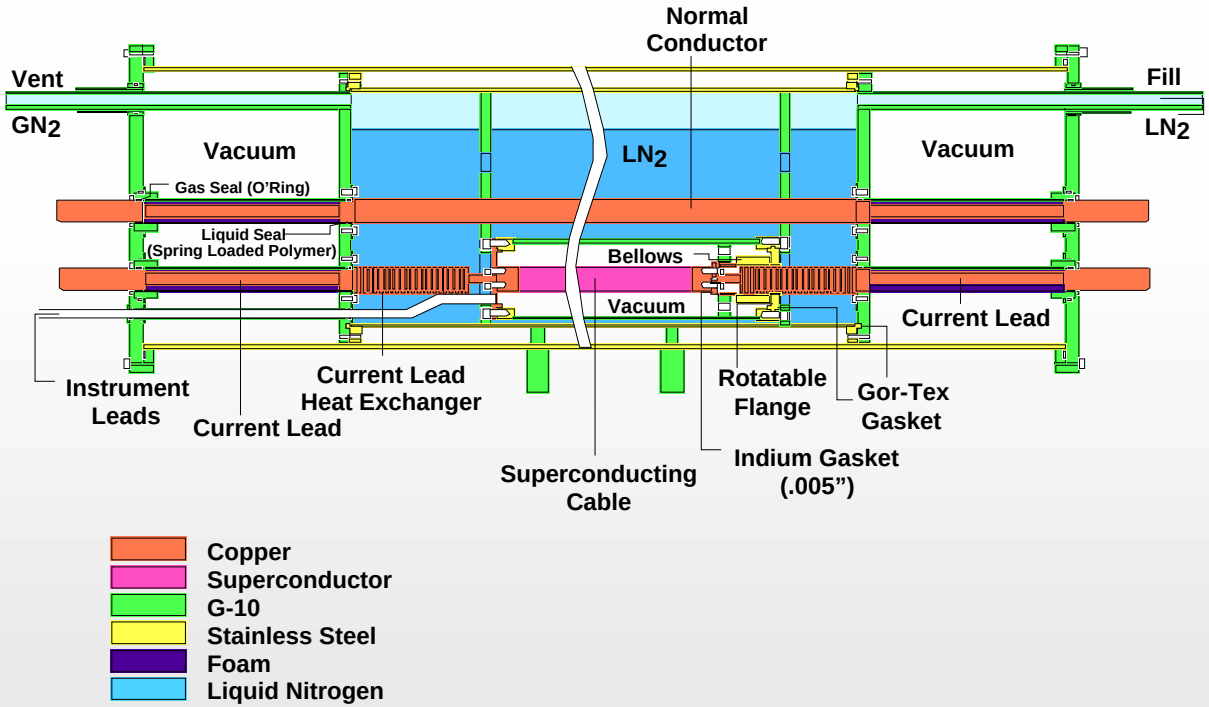


Ashworth, Maley, Suenaga, Foltyn, Willis, J. Appl. Phys. 88, 2718 (2000)

ac Loss Characterization

- Investigate ac losses in YBCO cables using LANL ac loss three-phase cable calorimeter
- Allows measurement of ac losses for warm-dielectric design HTS power cable

AC Loss Calorimeter



FY2001 Performance and Results

FY01 Goal: Begin staffing and equipment procurement for the IBAD/PLD facility in the Industrial Research Park

⇨ Space has been established for the new labs and offices; building construction is finished

⇨ Lab equipment procurement has begun; vacuum hardware and other equipment has been ordered

⇨ New staff has been hired (4 technical staff)

⇨ Initial contacts with possible partners have been made; Argonne, Brookhaven and Oak Ridge Nat'l Labs are committed to collaborating at the Research Park

Technology Integration

- Opportunity for new partnerships with industry, universities and national labs
- Minimize financial risk to companies
  Test concepts with small investment
- Co-location of industry with LANL now possible
- Basis for industrial collaborations can be User Facility Agreements and/or CRADA's
- New Industrial Internship program is now available
- Increased availability of Coated Conductor samples expected in the near future

FY2002 Plans

- Set up the Coated Conductor Labs at the Research Park
- Demonstrate working continuous processes for coated conductors
- Demonstrate *in-situ* monitoring/diagnostics capability
- ac-loss measurements on long coated conductors
- Establish an open environment for research and a user facility where various parties can work together
- Establish meaningful partnerships with interested parties

Conclusions

ACCI effort at Los Alamos is an aggressive program for Coated Conductor research and development with the goals for establishing the following:

- **High-throughput** sample preparation and characterization in **continuous** processing
- *In-situ* and *real-time* process diagnostics
- Applications effort using coated conductors
- Open environment for industrial partnerships
- User facility and training
- Educational opportunities for postdocs and students